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None

(58) Field of search
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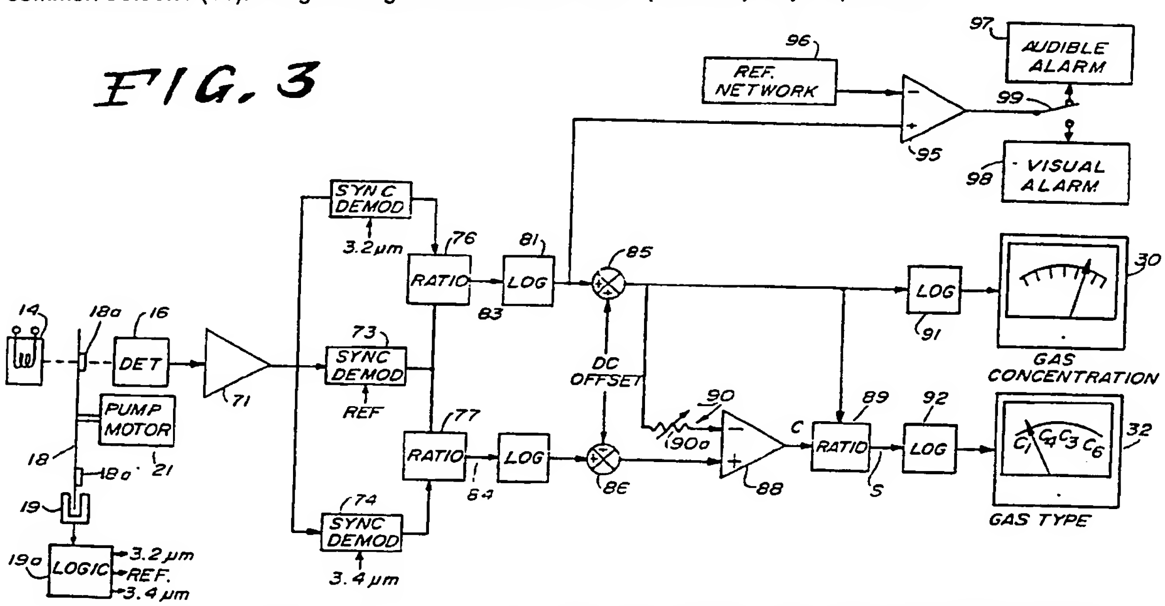
INT CL[4] G01N
Online database: WPI

(54) **Determining type and concentration of hydrocarbon gas**

(57) To determine the concentration and type of hydrocarbon gas in a gas sample (not shown), the absorption of infrared radiation by the sample is measured in two channels at different wavelengths. One channel at 3.2 microns provides a signal corresponding to approximately the sum of all hydrocarbons in the gas sample to a display 30, and the output of another channel at 3.4 microns is ratioed with the 3.2 micron channel output to provide a signal representative of the type or average type of hydrocarbon in the gas sample to another display 32. The outputs of the 3.2 and 3.4 micron channels may be ratioed with the output of a reference channel at 2.9 or 3.9 microns. The three wavelengths are provided from one source (14) by means of a filter wheel (18) which chops the light at a frequency which is used to demodulate the output of a common detector (16). A high total gas concentration alarm (97 or 98) may be provided.

FIG. 3



At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

This print takes account of replacement documents submitted after the date of filing to enable the application to comply with the formal requirements of the Patents Rules 1982.

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FIG. 1

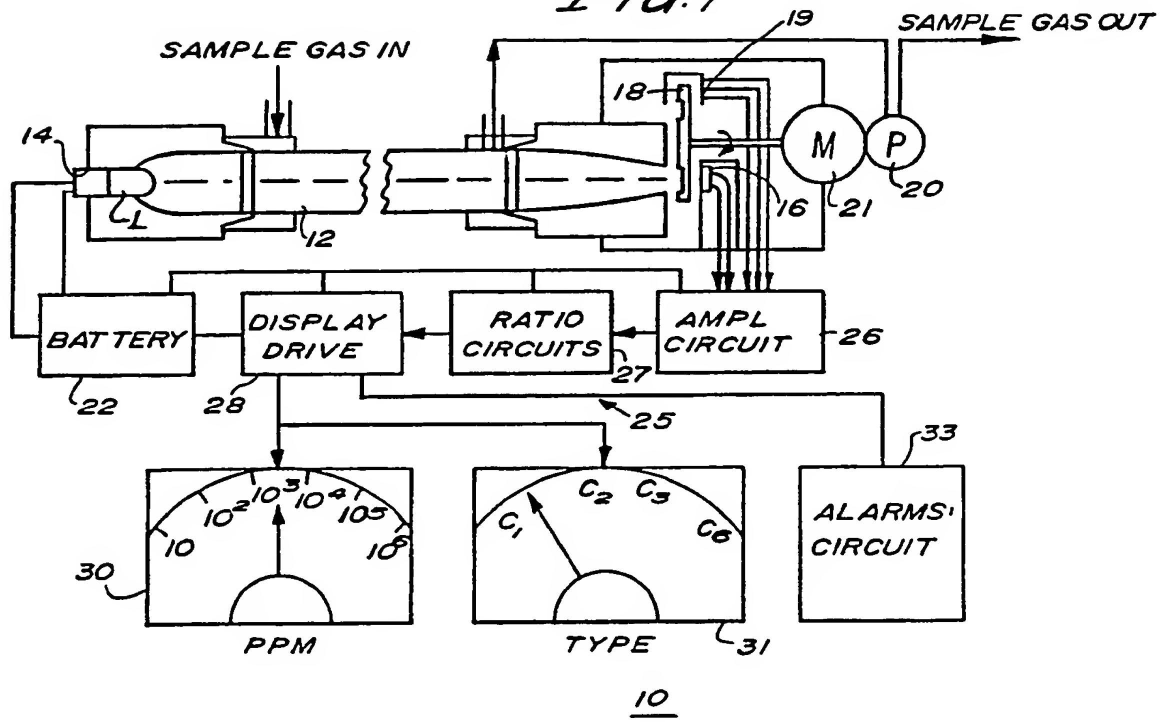
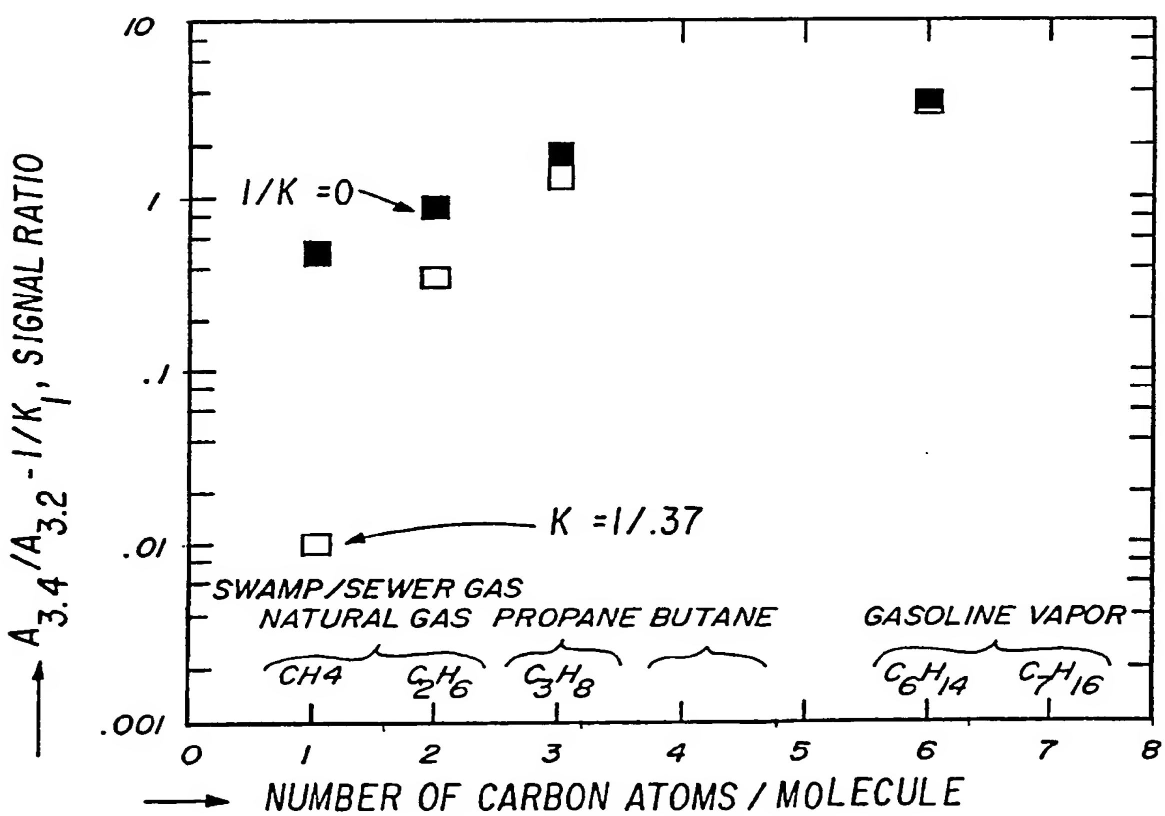

SAMPLE GAS IN
SAMPLE GAS OUT
14
L
12
18
19
M
P
20
21
16
BATTERY
DISPLAY DRIVE
RATIO CIRCUITS
AMPL CIRCUIT
26
27
22
28
25
33
10
10^2
10^3
10^4
10^5
10^6
C_1
C_2
C_3
C_6
ALARMS CIRCUIT
30
PPM
TYPE
31
10

FIG. 2


10
1
.1
.01
.001
1/K =0
K =1/.37
SWAMP/SEWER GAS
NATURAL GAS
PROPANE
BUTANE
GASOLINE VAPOR
CH4
C_2H_6
C_3H_8
C_6H_{14}
C_7H_{16}
0
1
2
3
4
5
6
7
8
$A_{3.4}/A_{3.2}-1/K_1$, SIGNAL RATIO
NUMBER OF CARBON ATOMS / MOLECULE

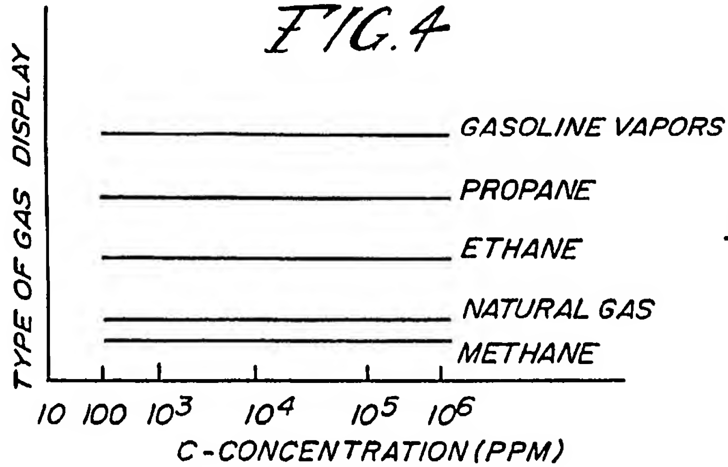

TYPE OF GAS DISPLAY
GASOLINE VAPORS
PROPANE
ETHANE
NATURAL GAS
METHANE
10 100 10^3 10^4 10^5 10^6
C-CONCENTRATION (PPM)

FIG.4

FIG.3

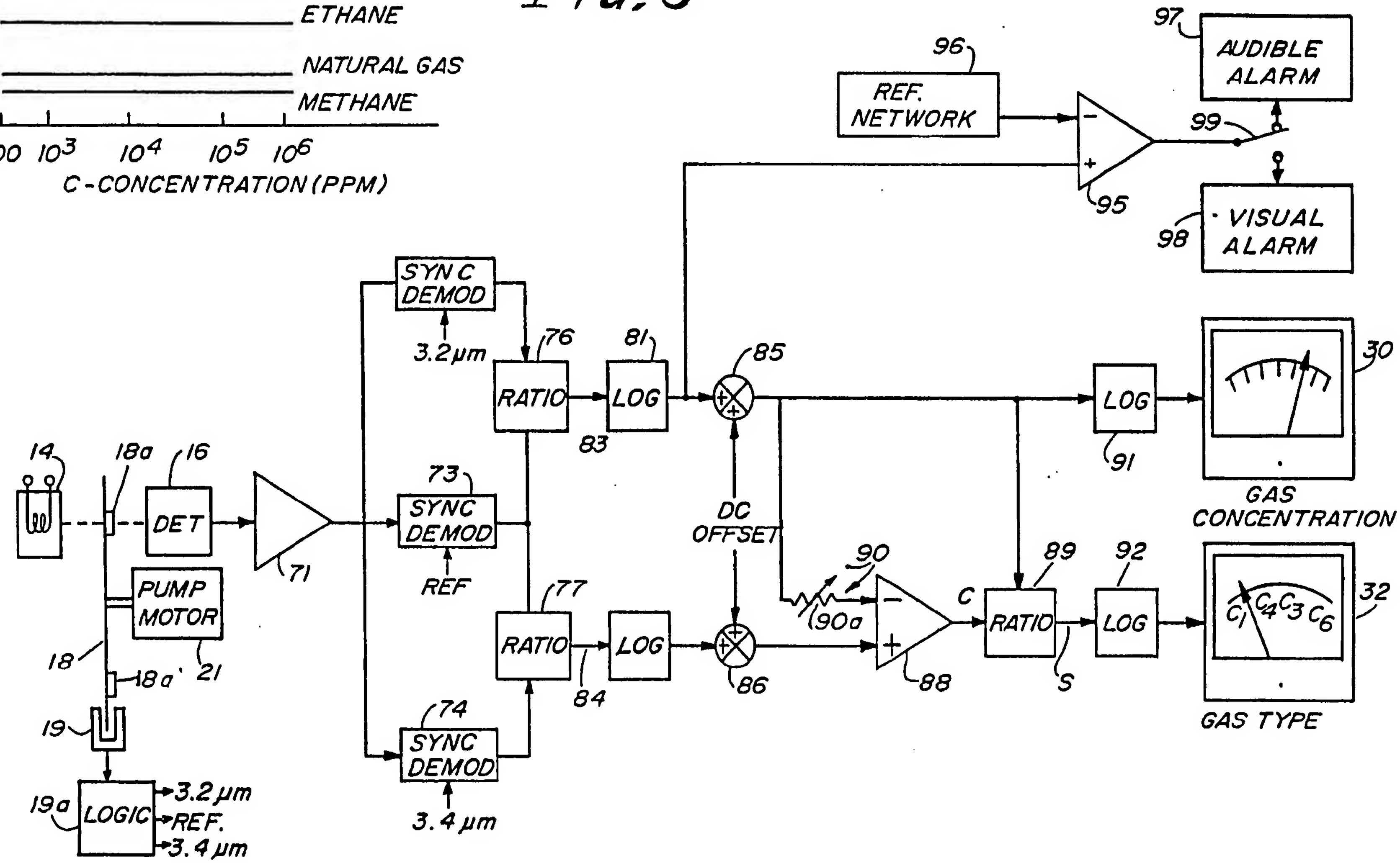

REF. NETWORK
96
97
AUDIBLE ALARM
99
95
98
VISUAL ALARM
SYNC DEMOD
3.2μm
76
81
RATIO
LOG
83
85
LOG
91
30
GAS CONCENTRATION
14
18a
16
DET
71
73
SYNC DEMOD
REF
DC OFFSET
90
90a
C
89
92
RATIO
LOG
S
88
86
32
C_1 C_4 C_3 C_6
GAS TYPE
PUMP MOTOR
21
18
18a'
19
77
RATIO
LOG
84
74
SYNC DEMOD
3.4 μm
19a
LOGIC
3.2 μm
REF.
3.4 μm

FIG. 5

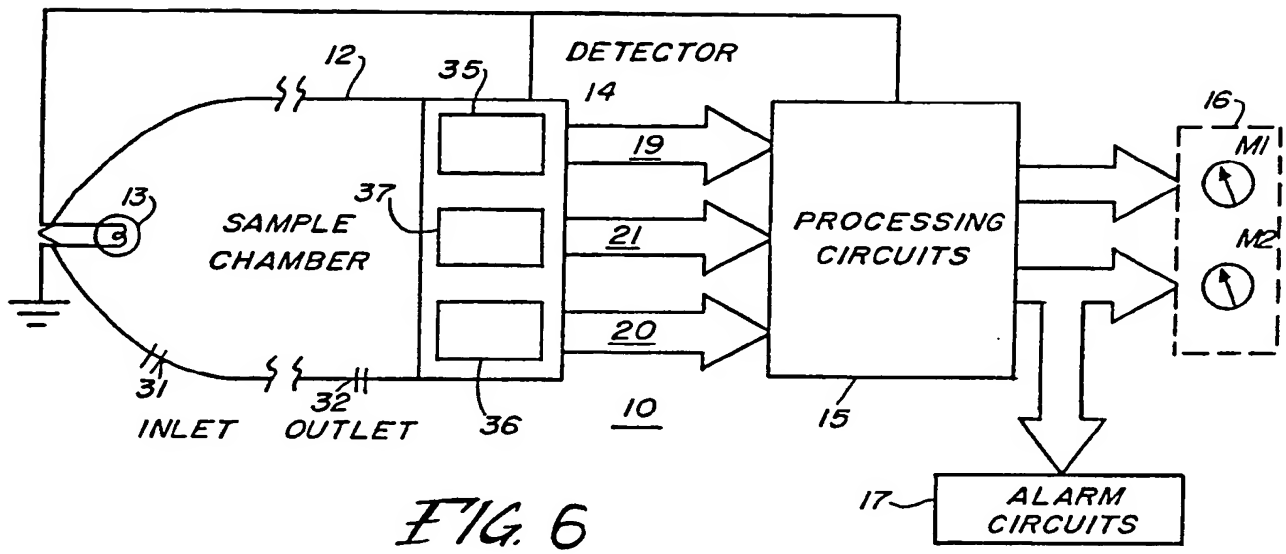


FIG. 6

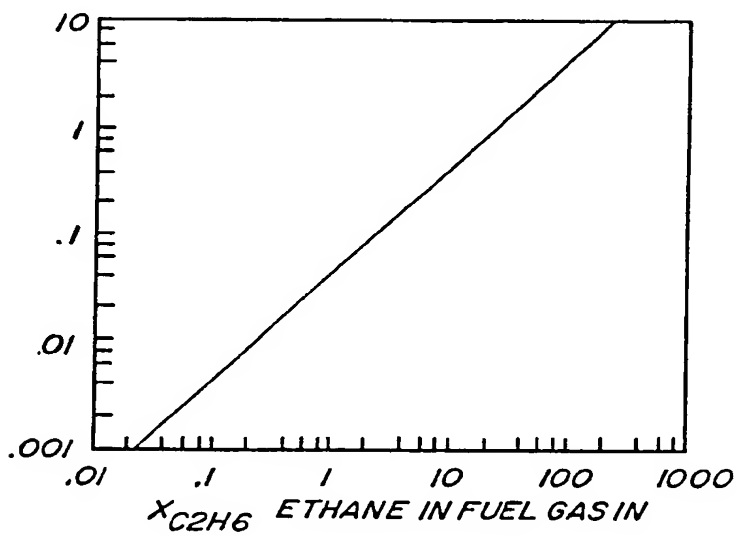


FIG. 8

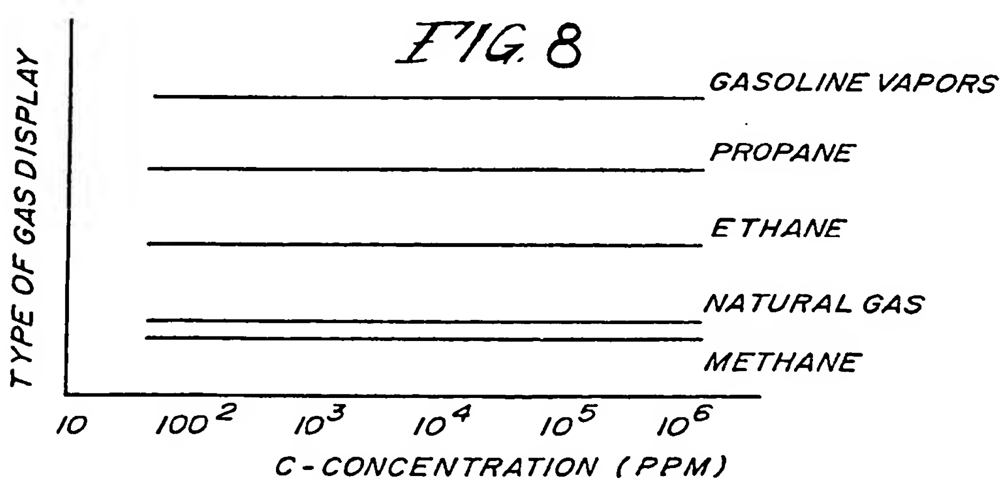
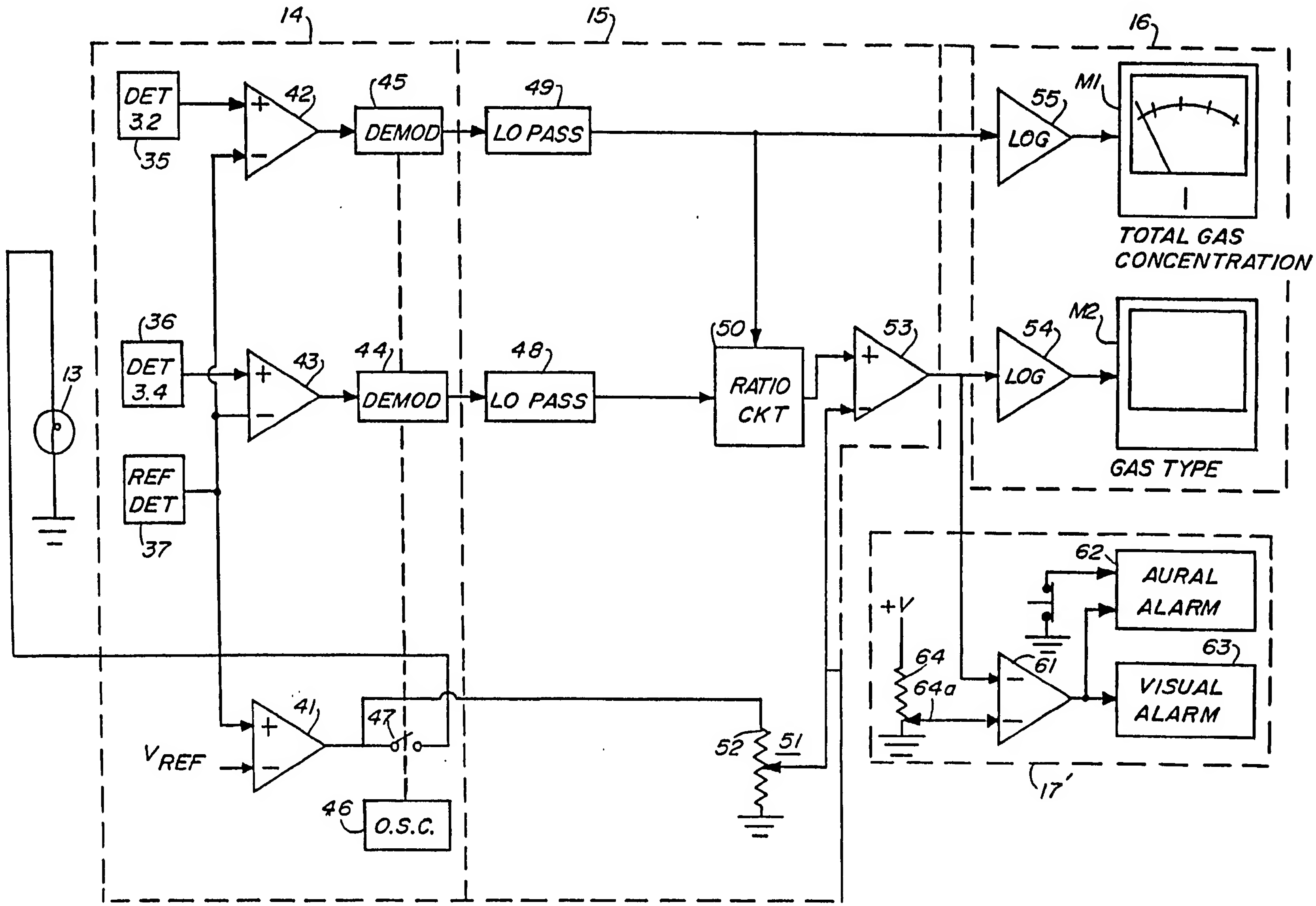


FIG. 7



DET 3.2
DET 3.4
REF DET
DEMOD
DEMOD
LO PASS
LO PASS
RATIO CKT
LOG
LOG
TOTAL GAS CONCENTRATION
GAS TYPE
AURAL ALARM
VISUAL ALARM
O.S.C.
V_{REF}
+V
14
15
16
17'
13
35
36
37
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
M1
M2
61
62
63
64
64a

SELECTIVE GAS DETECTING APPARATUS

Background of the Invention

This invention relates to gas detecting apparatus, and more particularly, to natural gas detecting apparatus of the type which operate on the basis of absorption of infrared light which is able to discriminate between pipeline natural gas, non-pipeline sources of methane, propane, and gasoline vapors.

Utilities which distribute natural gas require reliable, portable gas-leak detectors for use in maintenance of gas supply lines. Existing natural gas detectors are either costly, sensitive and non-selective or low cost, insensitive and non-selective. Non-selective gas detectors respond to any combustible gas. Selective gas detectors are specific to hydrocarbon gases. The two presently most used detectors are based on hydrogen flame ionization and on hot wire catalysis, cannot distinguish among different types of hydrocarbons. However, it is necessary to distinguish among different types of hydrocarbons in order to distinguish a pipeline gas from gasoline vapors or sewer or swamp gas and so reduce leak surveyor time wasted on false alarms. Ethane content, if measurable, provides a good means to discriminate between pipeline gas and interfering sewer or swamp gases because the latter contain practically no ethane, while pipeline gas does, in varying degrees. Gasoline vapors and propane (LP gas) can also generate a false alarm with conventional instruments.

However, their infrared absorption is shifted relative to that of methane, as will be described later, as it is the basis for this invention to eliminate sending false alarms.

In U.S. Patent 4,507,558, there is disclosed a selective detector for natural gas which discriminates between low concentrations of natural gas and other methane sources by measuring the characteristics of the methane/ethane ratio of natural gas as well as by using a combustible gas sensor. The operation of this detector is based on infrared light absorption of methane and ethane in combination with another non-specific combustible gas detector whereby the detector has the ability to detect non-specifically, the presence of a combustible gas, and to define the nature of the combustible gas. Thus, this natural gas detector utilizes two types of detection including non-dispersive infrared detectors and a non-specific combustible detector such as hot-wire catalytic combustible detector. The detector determines concentration of both methane or ethane irrespective of the concentration of the other gas by using absorption cells placed in front of the detectors. The detector includes a light emitting diode which issues light centered around 3.32 microns and a reference light source which emits light at a wavelength outside of this band. Although this arrangement permits distinguishing among different types of hydrocarbons, the requirement for a hot-wire catalytic combustible detector adds cost and complexity to the device and increases power consumption.

It would be desirable to have a natural gas detector which can distinguish among different types of hydrocarbons, and which provides information to the user on the amount and type of combustible gases in the environment.

Summary of the Invention

It is an object of the invention to provide an improved natural gas detector.

Another object of the invention is to provide a natural gas detector which can distinguish among different types of hydrocarbons.

Another object of the invention is to provide a natural gas detector which provides information to the user on the amount and type of combustible gases in the environment.

A further object of the invention is to provide a natural gas detector which is characterized by simplicity, greater response time and lower cost than known discriminating natural gas detectors.

A further object of the invention is to provide a natural gas detector having the ability to recognize propane leaks, or gasoline vapors or swamp or sewer gas.

A further object of the invention is to provide a natural gas detector which provides detection over the entire range of combustible gas without requirement for range switching for its display unit.

These and other objects are achieved by one embodiment of the present invention which has provided a selective gas detecting apparatus for determining the concentration and type or average type of hydrocarbon gas in a gas sample based upon absorption of infrared radiation by the gas sample. The gas detecting apparatus comprises means for passing infrared radiation through the gas sample, infrared radiation detecting means for detecting infrared radiation passed through the gas sample and producing in a first signal channel a first measurement signal indicative of a first wavelength absorbed by the gas sample, and producing in a second signal channel a second measurement signal indicative of a second wavelength absorbed by the gas sample, processing circuit means including first circuit means responsive to said first measurement signal for providing a first output signal corresponding to a first total concentration of hydrocarbons in the gas sample, second circuit means responsive to said second measurement signal for providing a second output signal corresponding to a second total concentration of hydrocarbons in the gas sample, first function generating circuit means for receiving said first output signal and providing a first absorbance signal corresponding to the natural logarithm of said first output signal and indicative of

absorbance by said gas sample of infrared radiation at said first wavelength, second function generating circuit means for receiving said second output signal and providing a second absorbance signal corresponding to the natural logarithm of said second output signal and indicative of absorbance by said gas sample of infrared radiation at said second wavelength, ratio determining means responsive to said first and second absorbance signals for providing a ratio signal corresponding to the ratio of said first and second absorbance signals, said ratio signal being indicative of the type or average type of hydrocarbon in the gas sample, and display means responsive to said first absorbance signal and said ratio signal for providing an indication of the concentration and type or average type of hydrocarbon gas in the gas sample, respectively.

All working or main absorption channels use the infrared absorption of light energy by the carbon-hydrogen bonds in hydrocarbons, which shift in intensity in characteristic ways as the structure or chain length of the hydrocarbon changes. These shifts occur within about 3.0 to 3.8 microns for the fundamental C-H excitation and around 1.6 microns for the first harmonic excitation.

In another preferred embodiment of this invention, ratio determining means are responsive to said first and second output signals for providing a ratio signal corresponding to the ratio of said first and second output signals, said ratio signal being

indicative of the type or average type of hydrocarbon, and display means responsive to said second output signal and said ratio signal for providing an indication of the concentration and type or average type of hydrocarbon gas in the gas sample, respectively.

These shifts occur within about 3.0 to 3.8 microns for the fundamental C-H excitation and around 1.6 microns for the first harmonic excitation. All working or main absorption channels use the infrared absorption of light energy by the carbon-hydrogen bonds in hydrocarbons, which shift in intensity in characteristic ways as the structure or chain length of the hydrocarbon changes.

The invention consists of certain novel features and structural details hereinafter fully described, illustrated in the accompanying drawings, and particularly pointed out in the appended claims, it being understood that various changes in the details may be made without departing from the spirit, or sacrificing any of the advantages of the present invention.

Description of the Drawings

For the purpose of facilitating and understanding the invention, there is illustrated in the accompanying drawings a preferred embodiment thereof, from an inspection of which, when

considered in connection with the following description, the invention, its construction and operation, and many of its advantages will be readily understood and appreciated.

FIG. 1 is a simplified representation of the natural gas detector provided by one preferred embodiment of the present invention;

FIG. 2 is a graphic representation of the relationship between the signal output of the type or average type of the gas detector display versus different but individual types of hydrocarbons in a gas sample;

FIG. 3 is a block diagram of the natural gas detector provided by the present invention;

FIG. 4 is a graphical representation of the type of gas display of the detector versus individual gas concentrations;

FIG. 5 is a simplified block diagram of the natural gas detector provided by another preferred embodiment of the present invention;

FIG. 6 is a graphical representation of ethane concentration in mixtures with methane compared to a ratio of infrared absorption signals at different wavelengths;

FIG. 7 is a detailed block diagram of the natural gas detector provided by the present invention; and

FIG. 8 is a graphical representation of the type of gas display of the detector versus individual gas concentrations.

Description of Preferred Embodiments

Referring to FIG. 1, the operation of the natural gas detecting apparatus 10 provided by one preferred embodiment of the present invention is based upon the absorption of infrared energy by a gas sample as the gas sample is pumped through a gas sample chamber defined by an optical cell 12. The natural gas detector 10 includes a gas detection arrangement which determines gas concentration, i.e. the total concentration of hydrocarbons in the gas sample, and the gas type, i.e. swamp or sewer gas, natural gas, propane, gasoline vapors and others. The gas sample is analyzed using optical cell 12 which defines a gas sample optical path length, an infrared radiation source 14 and an infrared radiation detector 16 with a rotatable chopper wheel 18 interposed therebetween. A pump 20 moves the sample gas through the optical cell 12 at the rate of about two liters per minute. The pump 20 is driven by a motor 21 which also drives the chopper wheel 18. The use of a common motor 21 to drive the chopper wheel 18 and the pump 20 reduces power requirements for the natural gas detector 10. The gas detecting apparatus 10 is energized from a battery 22 which may comprise a 12 volt (or two

five volt) rechargeable nickel cadmium battery providing power for long hours of operation. The gas detecting apparatus consumes only four watts including the one watt pump 20.

The infrared radiation detector 16 detects infrared radiation in selected bands and produces electrical measurement signals at the wavelengths absorbed by the gases in the sample, and thus indicative of the gases which comprise the sample. Timing signals for use in processing the measurement signals are generated by a non-contacting type pickup 19 which may be an optical, magnetic or capacitive type device.

The signals produced by the detector 16 and the pickup 19 are applied to processing circuits indicated generally at 25. The processing circuits 25 include an amplifier and demodulating circuit 26, ratio circuits 27, and a display drive circuit 28 which provides drive signals for a pair of analog meters 30 and 32. An alarm circuit 33 provides an alarm indication whenever a preselected gas concentration level is reached or exceeded.

In accordance with one aspect of the invention, the natural gas detector uses selection of two infrared wavelengths 3.2 microns and 3.4 microns to determine concentration and type of hydrocarbon gas. Gas concentration is processed and displayed in terms of absorbance to minimize error. A representation of gas concentration is displayed by meter 30. To provide an indication of gas type, the processing circuits 25 of the gas detecting

apparatus 10 compute the ratio of absorbances to obtain a signal indicative of the type of hydrocarbon gas in air and which is independent of gas concentration. This information is displayed by meter 32.

Considering the gas detector 10 in more detail, the optical cell 12 is about 25-100 centimeters in length and preferably 50 cm. The inner surface of the optical cell has a coating of gold to internally reflect the radiation directed thereto. The optical cell receives a sample of a gas to be analyzed via the suction action of the pump 20 which draws the gas sample into the optical cell through an inlet 41 and exhausts the gas sample from the optical cell 12 through an outlet 42. The light from the infrared radiation source is optically collimated by a reflector 43, channeled through the internally reflecting optical cell 12 and is concentrated by a parabolic, non-imaging concentrator 44 located forward of the detector 16. The optical cell 12 has windows 45 and 46 on each end which are sealed to the parabolic surfaces of the reflectors 43 and 44. The gas sample is applied to the optical cell 12 by a detector sample wand (not shown) which is attached to the inlet 41 of the optical cell. A suitable outlet hose (not shown) is connected between the outlet 42 and the pump 20.

The infrared radiation source 14 comprises a tungsten subminiature light bulb. To increase sensitivity, the output of the light source is mechanically chopped at a 50 to 1000 Hz (preferably 300) rate by the action of the chopper wheel 18.

Referring to FIGS. 1 and 3, the chopper wheel 18 is driven by the same motor 21 which operates the pump 20. The chopper wheel, may for example, comprise a one inch diameter disc with the separation between the optical axis and the chopper wheel axis being one-quarter inches in one embodiment. The chopper wheel 18 carries a plurality of narrow band interference filters 18a including filters at the two wavelengths 3.2 microns and 3.4 microns, and a reference wavelength which may be 2.9 or 3.9 microns, which only provide passage of infrared radiation at wavelengths 3.2 microns, 3.4 microns and 2.9 (or 3.9) microns to the infrared radiation detector 16. The non-contacting pickup 19 generates gating or phase timing signals for these three channels for demodulating the detection signals.

The signal output of the detector 16 is applied to the amplifier and demodulator circuit 26, the output of which is processed by ratio circuit 27 to obtain signals representative of absorbance and of the ratio of absorbances. These signals are applied to display drive circuit 28. The use of logarithmic values for purposes of display results in compression of the displayed information, obviating the need for range switching of the analog display meters.

Referring to FIG. 3, which illustrates the natural gas detecting apparatus 10 in simplified form, with the gas sample chamber omitted, signals detected by the detector 16 are applied to the input of the amplifier and demodulator circuit 26 which includes a buffer amplifier 71 and sync demodulator circuits 72-74. The output of amplifier 71 is commonly connected to the inputs of the demodulator circuits 72-74. The sync demodulator circuits 72, 73 and 74 have reference inputs which receive the phase reference signals generated by the pickup 19 and associated logic 19a. The chopper wheel produces an operating rate of 300 Hz for the detector. The sync demodulator circuits 72, 73 and 74 provide detector output signals indicative of the detection of wavelengths of 3.2 microns, 2.9 microns (or 3.9 microns), and 3.4 microns, respectively, each $\pm$ 0.1 microns. The signal outputs of sync demodulator are applied to the ratio circuits 27.

The ratio circuits 27 include a function generating circuit 76, a function generating circuit 77 and logarithm circuits 81 and 82. The ratio circuits 27 define two signal channels 83 and 84 for producing measurement signals corresponding to wavelengths at 3.2 microns and 3.4 microns, respectively, each indicative of a total concentration of hydrocarbons in the gas sample. A DC offset signal may be introduced into each of the signal channels by summing circuits 85 and 86.

Function generating circuit 76 provides a signal corresponding to the quotient of detector signal at 3.2 microns and the reference signal at 2.9 microns (or 3.9 microns). Function generating circuit 77 provides a signal corresponding to the quotient of detector signal at 3.4 microns and the reference signal at 2.9 microns (or 3.9 microns). The signal output provided by function generating circuit 76 is applied to logarithm circuit 81 which generates a signal corresponding to the natural log of its input signal. Similarly, the log of the signal provided by function generating circuit 77 is obtained by log circuit 82.

The signal channel at a wavelength near 3.2 microns measures the transmission: (1) $I/Io = \exp(-kpC) = \exp(-x)$ where Io is intensity without hydrocarbons in the optical path, I is intensity with hydrocarbons in the optical path, $(I-Io)/Io$ equals absorption, k is the absorption coefficient, x is absorbance, p is the optical path length in centimeters and C is concentration in parts per million (ppm).

Thus, the signals produced by logarithm circuits 81 and 82 represent absorbances. Absorbances are formulated and processed in signal channels 83 and 84 to minimize drifts at low concentrations and to maximize linearity at high concentrations.

The use of 3.2 microns and 3.4 microns provides a balance between discrimination among different hydrocarbons and commonality among them such that the total concentration of hydrocarbons is obtained from channel 83 and channel 84 is used to determine the type of hydrocarbon by obtaining the ratio of the signal in channel 84 relative to the signal in channel 83. Thus, the signal conducted in signal channel 83 represents the gas concentration. Signal channel 84 further includes a subtractor circuit 88, a function generating circuit 89 and an offset network 90 including variable resistance 90a which defines an offset factor 1/K1. In one embodiment, the value of the offset factor 1/K1 was 0.37. In signal channel 84, the signal conducted in signal channel 83 is applied through resistance 90a to the inverting input of subtractor circuit 88 which receives the signal in channel 84 at its non-inverting input. The signal output of the subtractor circuit 88 is applied to function generating circuit 89 which provides an output signal S which corresponds to the quotient of the signals in channels 84 and 83 and represents the type of hydrocarbon gas present in the sample gas.

Computation of the ratio of absorbances by function generating circuit 89 produces a signal which is indicative of the type or average type of hydrocarbon gas in air and largely independent of the concentration of the gas, as indicated by FIG. 4.

The absorbance signal in channel 83 is applied to logarithm circuit 91 which produces a drive signal for meter 30. Similarly the signal S representing the ratio of absorbances produced by function circuit 89 is applied to logarithm circuit 92 which produces a drive circuit for meter 32. Use of logarithmic values of the signals compresses the drive signals for the meters 30 and 32 and obviates the need for range switching. Very small values for the signal S indicate the presence primarily of methane. The value of offset factor K1 is chosen to make the signal S approximately equal to zero for methane. A small addition of higher hydrocarbons (C2 to C6 or higher) increases the measured value of signal S because of the shift in absorption of these hydrocarbons towards longer wavelengths. A small scale reading at C1 is indicative of swamp gas. A near mid-scale reading near C1 but between it and C2 is indicative of natural gas. A reading at C3 above mid scale is indicative of propane. A near full scale reading at C6 is indicative of gasoline vapors.

The gas detecting apparatus 10 measures the entire concentration range of methane from 10 to 10^6ppm and displays the result without range switching of the meters 30 and 32. FIG. 2 illustrates the results of measuring the signal S as the concentration shifted from methane to hexane and the number of carbon atoms per molecule increases from one to six, for an offset factor equal to zero, and for an offset factor equal to

0.37. The graph of FIG. 4 illustrates that signals obtained in signal channel 84 corresponds to the type of gas, rather than quantity or concentration of gas.

The alarm circuit includes a comparator circuit 95 which compares the amplitude of the signal in channel 83 with a reference value established by reference network 96 and energizes an audible alarm device 97 or a visual alarm device 98 as a function of the setting of a manually operated switch 99. The alarm circuit 33 provides an audible or visual alarm whenever the measured concentration in parts per million (ppm) surpasses an adjustable upper limit established by the reference network. This allows the user to concentrate on the sample collecting process rather than having to watch the meters 30 and 32 continuously.

Referring to FIG. 5, the natural gas detector 10′ provided by another preferred embodiment of the present invention operates on the basis of absorption of infrared (IR) energy by a gas sample pumped through a gas sample chamber defined by an optical cell 12′. The natural gas detector 10′ includes a detection arrangement in which gas concentration is determined using an appropriate optical cell 12′ which defines a gas sample optical path length of 50 centimeters in the exemplary embodiment, a source of infrared radiation 13′, an infrared

radiation detecting circuit 14′, processing circuits 15′, a display unit 16′ including analog meters M1 and M2, and an alarm circuit 17′.

In accordance with one aspect of the invention, the natural gas detector 10′ uses two signal channels 19′ and 20′ and two infrared wavelengths for measurement of absorption of methane and ethane in determining the amount and type of source of combustible gases in an environment. In the preferred embodiment, one wavelength is 3.2 ± 0.1 microns and the other wavelength is 3.4 ± 0.1 microns. A reference signal at a wavelength of 2.9 (or 3.9) ± 0.1 microns is provided in a third channel 21′. The wavelengths for measurement of the two channels at 3.2 microns and 3.4 microns are selected so that one infrared absorption channel 19′ (at 3.2 microns) provides a measurement signal corresponding to the total concentration or sum of ethane and methane and other hydrocarbons in the gas sample. The other infrared absorption channel 20′ (at 3.4 microns) provides a second measurement of total hydrocarbon concentration in the gas sample. For a gas mixture containing only air, methane and ethane, the processing circuits 15′ determine the percentage of ethane in such a natural gas simulant. With real natural gas, the detector provides a first output signal indicating on the one hand, the sum of all hydrocarbon concentrations in the gas sample, and a second output signal indicating, on the one hand, the presence of swamp or sewer gas, natural or propane in the gas sample. The output signals are applied to the display unit

16'. The gas measurement information displayed by the gas detector 10' includes total gas concentration which is represented by the sum of all hydrocarbons, including methane and ethane and displayed by the first meter M1, and the gas type or average gas type i.e. methane (sewer) gas, pipeline (natural) gas, or concentrations of propane gas or gasoline vapors, displayed by the second meter M2.

More specifically, the optical chamber 12' is interposed between the source 13' of the infrared radiation and the detecting circuit 14' and has a gas inlet 31' near one end thereof and a gas outlet 32' near the opposite end thereof. The infrared radiation source may be a tungsten subminiature light bulb, for example.

The detecting circuit 14' includes a detector 35' associated with infrared absorption channel 19', a detector 36' associated with infrared absorption channel 20' and a reference detector 37' associated with both absorption channels 19' and 20'. The detectors 35'-37' may each comprise a PbSe sensor. The signal in absorption channel 19' is applied to an analog meter M1 which provides a reading indicative of total gas concentration, or the amount of methane, ethane and other hydrocarbons in air. The signal in absorption channel 19' is combined with the signal in absorption channel 20' to provide an output which is displayed by analog meter M2 indicative of the type of hydrocarbon in the gas sample under test, with a small

reading signifying swamp or sewer gas, a low to mid-scale reading being representative of natural gas, a midscale reading indicating propane and a reading near full scale signifying gasoline vapors. In accordance with a feature of the invention, the meters M1 and M2 have logarithmic scales so that range switching is not required.

Referring to FIG. 6, there is illustrated a relationship between percent of ethane in a fuel gas sample as a function of the ratio of the absorption signal at 3.4 microns to that at 3.2 microns. The scales are logarithmic and accordingly, the data provides a straight line display.

Considering the circuits of the gas detector 10′ in more detail, with reference to FIG. 7, the detecting circuit 14′ further includes three operational amplifier circuits 41′, 42′ and 43′, each connected for operation as a subtracting circuit, a demodulating circuit 44′, a demodulating circuit 45′, an oscillator circuit 46′ and a switch 47′.

The processing circuits 15′ include a low pass filter 48′, a low pass filter 49′, a ratio determining circuit 50′ and a reference circuit 51′ including a potentiometer 52′, and an operational amplifier circuit 53′ which is connected for operation as a subtracting circuit.

The display unit 16', further includes a logarithmic amplifier 54' associated with meter M2 and a logarithmic amplifier 55' associated with meter M1.

Amplifier 41' has its non-inverting input connected to a source of reference potential VREF and its inverting connected to the output of the reference detector 37'. The source of infrared radiation 13' is connected to the output of amplifier 41' in series with switch 47'. The oscillator circuit 46' generates a signal at 10 Hz which controls the operation of switch 47' to provide intermittent driver at a 10 Hz rate for the tungsten lamp which comprises the source of infrared radiation 13'.

Absorption channel 19' includes amplifier 42' which is connected for operation as a subtracting circuit, demodulating circuit 45', low pass filter 49' and a logarithmic amplifier 55'. Amplifier 43' has its non-inverting input connected to the output of detector 35' and its inverting input connected to the output of the reference detector 37'. The output of the amplifier circuit 43' is connected to the demodulating circuit 45' which receives the 10 Hz phase signal from the oscillator 46'. The signal output of the demodulating circuit 45' is passed through the low-pass filter 49', which is set at 1 Hz, for eliminating the pulsing effect of the 10 Hz drive, providing a DC output signal which is applied to the logarithmic amplifier 55'. The logarithmic amplifier 55' responsively generates

outputs a signal representing the concentration of methane and ethane in air. The signal output of the logarithmic amplifier 55′ is applied as a drive signal to the analog meter M1.

Infrared absorption channel 20′ includes operational amplifier 42′ which is connected for operation as a subtracting circuit, demodulating circuit 44′, low-pass filter 48′, a ratio determining circuit 50′, operational amplifier 53′ of reference circuit 51′ and logarithmic amplifier 54′. The amplifier 43′ has its non-inverting input connected to the output of detector 36′ and its inverting input connected to the output of the reference detector 37′. The output of amplifier 42′ is connected to the input of demodulating circuit 44′ which receives a phase signal at 10 Hz from the oscillator 46′. The signal output of the demodulating circuit 44′ is passed through low-pass filter 48′ which attenuates above 1 Hz to provide a DC output signal. The ratio determining circuit 50′ produces a ratio signal S′ corresponding to the quotient or ratio of the signal in channel 20′ to the signal in channel 19′. The ratio signal produced by of ratio circuit 50′ is applied to the non-inverting input of subtracting circuit 53′ which receives at its inverting input an offset signal 1/k1. The value of the offset is selected to cause the value of the ratio signal S′ to be zero when the gas sample is methane. In an exemplary embodiment, the value of k1 was 1.333. The signal output of amplifier 53′ is applied to the logarithmic amplifier 54′ which provides drive signals for meter M2 which signals are indicative of the type or average type of

hydrocarbon gas in air and largely independent of the concentration of the gas, as indicated by FIG. 8. The scale of meter M2 has three defined regions A, B, and C for signifying detection of swamp gas, natural gas and propane/gasoline vapors, respectively.

The alarm circuit 17′ includes a comparator 61′, an audible alarm device 62′ and a visual alarm device 63′ which are commonly connected to the output of the comparator 61′. The comparator circuit 61′ has its inverting input connected to the wiper 64a′ of to receive a reference signal generated by potentiometer 64′ and its non-inverting input connected to the output of ratio determining circuit 50′ of the absorption channel 20′. The reference level is set by adjusting potentiometer 64′ to provide an alarm whenever a minimum amount of ethane is detected by the gas detector 10′.

Referring to FIG. 7, in use, the tungsten light which comprises infrared radiation source 13′ is driven by the oscillator 46′ at a 10 Hz rate. The gas sample being tested is pumped through the sample chamber 12′ (FIG.5) from its inlet 31′ to its outlet 32′. The light output is directed through the sample chamber 12′ (FIG. 5) which contains the gas sample being analyzed. Amplifier 41′ and reference infrared detector 37′ form a compensation circuit, supplying a signal to the inverting inputs of amplifiers 42′ and 43′, as well as to amplifier 41′, to compensate for variations in the infrared radiation level

produced by the source 13'. Demodulating circuits 44' and 45' synchronize measurement by the detectors 35'-37' of absorption of infrared radiation by the gas sample with the "on" time of the tungsten lamp which comprises the infrared radiation source. The detectors 35', 36' and 37' provide measurement signals indicative of the absorption of infrared radiation at wavelengths 3.2 microns, 3.4 microns and 2.9 (or 3.9) microns, respectively. Low pass filters 49' and 48' eliminate the effect of the 10 Hz electronic chopping of the light output of the source 13' on the detection signals in signal channels 19' and 20'. In absorption channel 19' passed through the low-pass filter 49', which is a DC signal representative of the sum of methane and ethane in the gas sample is applied to amplifier 55'. The logarithm of the measurement signal is obtained by the logarithmic amplifier 55' and applied to meter M1 which indicates concentration in parts per million PPM.

In absorption channel 20', the measurement signal passed through low-pass filter 48' which is a DC signal indicative of the difference in the concentration of methane and ethane in the gas sample is applied to ratio determining circuit 50' which also receives the measurement signal in channel 19'. This measurement signal in channel 20' is divided by the measurement signal in absorption channel 19', the resultant ratio signal being representative of the type of hydrocarbon in the gas sample. The factor 1/k1 is subtracted from the ratio signal by subtracting circuit 53'. The logarithm of the resultant ratio

signal is obtained by logarithmic amplifier 54′ and applied to meter M2. A small reading, 0-0.1 percent on the panel meter M2 that the gas sample is signifies swamp or sewer gas. An intermediate reading 1-10 percent is indicative that the gas sample is natural gas. A reading above 20 percent or 30 percent is indicative of that the gas sample contains concentrations of propane or gasoline vapors.

CLAIMS

1. A selective gas detecting apparatus for determining a concentration and type or average type of hydrocarbon gas in a gas sample based upon absorption of infrared radiation by the gas sample, comprising: sampling means for passing infrared radiation through the gas sample, infrared radiation detecting means for detecting infrared radiation passed through the gas sample and producing in a first signal channel a first measurement signal indicative of a first wavelength absorbed by the gas sample, and producing in a second signal channel a second measurement signal indicative of a second wavelength absorbed by the gas sample, processing circuit means including first circuit means responsive to said first measurement signal for providing a first output signal corresponding to an indication of a first total concentration of hydrocarbons in the gas sample, second circuit means responsive to said second measurement signal for providing a second output signal corresponding to an indication of a second total concentration of hydrocarbons in the gas sample, first function generating circuit means for receiving said first output signal and providing a first absorbance signal corresponding to a natural logarithm of said first output signal and indicative of absorbance by said gas sample of infrared radiation at said first wavelength, second function generating circuit means for receiving said second output signal and providing a second absorbance signal corresponding to the natural logarithm of said

second output signal and indicative of absorbance by said gas sample of infrared radiation at said second wavelength, ratio determining means responsive to said first and second absorbance signals for providing a ratio signal corresponding to the ratio of said first and second absorbance signals, said ratio signal being indicative of the type or average type of hydrocarbon in the gas sample, and display means responsive to said first absorbance signal and said ratio signal for providing and indication of the concentration and type or average type of hydrocarbon gas in the gas sample, respectively.

2. A gas detecting apparatus according to Claim 1, wherein said first wavelength is 3.2 ± 0.1 microns and said second wavelength is 3.4 ± 0.1 microns.

3. A gas detecting apparatus according to Claim 2, wherein said infrared radiation detecting means produces a reference measurement signal indicative of a third wavelength absorbed by the gas sample, said reference measurement signal being applied to said first and second circuit means for generating said first and second output signals.

4. A gas detecting apparatus according to Claim 3, wherein said third wavelength is 2.9 ± 0.1 microns.

5. A gas detecting apparatus according to Claim 3, wherein said third wavelength is 3.9 ± 0.1 microns.

6. A gas detecting apparatus according to Claim 3, wherein said processing circuit means further comprises offset means for adjusting said ratio signal to be a preselected value when the ratio signal indicates that the type of hydrocarbon is methane.

7. A gas detecting apparatus according to Claim 6, wherein said offset means includes means for producing an offset signal and circuit means for subtracting said offset signal from said first absorbance signal at the input of said ratio determining means.

8. A gas detecting apparatus according to Claim 3, wherein said display means comprises first and second analog meters and third and fourth function generating circuit means, said third function generating circuit means being interposed between said ratio determining means and said first meter and responsive to said ratio signal for providing a signal corresponding to the logarithm of said ratio signal for driving said first meter, and said fourth function generating circuit means being interposed between said first function generation means and said second meter and responsive to said second absorbance signal for providing a signal corresponding to the logarithm of said second absorbance signal for driving said second meter.

9. A gas detecting apparatus according to Claim 3, further comprising alarm means responsive to said second absorbance signal for providing an indication whenever a measured concentration exceeds a preselected level.

10. A gas detecting apparatus according to Claim 3, wherein said ratio determining means comprises a function circuit providing a signal output corresponding to a quotient of said first and second output signals.

11. A gas detecting apparatus according to Claim 4, wherein said infrared radiation detecting means comprises a single infrared detector, a chopper disc member bearing narrow band interference filter means interposed between said infrared source and said detector and rotatably mounted to present passage in sequence of infrared radiation at 3.4 microns, 3.2 microns, and 2.9 microns to said detector, pickup means for generating a plurality of reference signals in sequence with the interference of passage of infrared radiation in said related bands to said detector, first demodulating circuit means responsive to said signal outputs of said detector and to a first one of said reference signals to produce said first measurement signal, and second demodulating circuit means responsive to said signal outputs of said detector and to a second one of said reference signals for producing said second measurement signal.

12. A gas detecting apparatus according to Claim 11, wherein said gas sampling means includes means defining a gas sample chamber having a fluid inlet and a fluid outlet, a fluid pump means for moving the gas sample through said sample chamber and drive means for driving said pump means, said drive means being coupled to said disc member for rotating said disc member.

13. A selective gas detecting apparatus for determining a concentration and type or average type of hydrocarbon gas in a gas sample based upon absorption of infrared radiation by the gas sample comprising: means for passing infrared radiation from a source of infrared radiation through the gas sample, infrared detecting means for detecting infrared radiation passed through the gas sample including a single infrared detector and filter means interposed between said source of infrared radiation for producing a first detection signal indicative of a first wavelength absorbed by the gas sample, a second detection signal indicative of a second wavelength absorbed by the gas sample, and a reference signal indicative of a third wavelength absorbed by the gas sample, first demodulating circuit means responsive to detection signals provided by said detector and to said reference signal to produce a first measurement signal indicative of said first wavelength absorbed by the gas sample, second demodulating circuit means responsive to detection signals provided by said detector and to said reference signal to produce a second measurement signal indicative of said second wavelength absorbed by the gas sample, processing circuit means

including first circuit means responsive to said first measurement signal for providing a first output signal corresponding to a first total concentration of hydrocarbons in the gas sample, second circuit means responsive to said second measurement signal for providing a second output signal corresponding to a second total concentration of hydrocarbons in the gas sample, first function generating circuit means for receiving said first output signal and providing a first absorbance signal corresponding to the natural logarithm of said first output signal and indicative of absorption by said gas sample of infrared radiation at said first wavelength, second function generating circuit means for receiving said second output signal and providing a second absorbance signal corresponding to the natural logarithm of said second output signal and indicative of absorption by said gas sample of infrared radiation at said second wavelength, ratio determining means responsive to said first and second absorbance signals for providing a ratio signal corresponding to the ratio of said first and second absorbance signals, said ratio signal being indicative of the type or average type of hydrocarbon gas, and display means responsive to said first absorbance signal and said ratio signal for providing an indication of the concentration and type of hydrocarbon gas in the gas sample.

14. A gas detecting apparatus according to Claim 13, wherein said first wavelength is 3.2 microns, said second wavelength is 3.4 microns and said third wavelength is 3.9 microns.

15. A gas detecting apparatus according to Claim 13, wherein said first wavelength is 3.2 microns, said second wavelength is 3.4 microns and said third wavelength is 2.9 microns.

16. A gas detecting apparatus according to Claim 15, wherein said processing circuit means further comprises offset means for adjusting said ratio signal to be a preselected value when the ratio signal indicates that the type of hydrocarbon is methane.

17. A gas detecting apparatus according to Claim 16, wherein said offset means includes means for producing an offset signal and circuit means for subtracting said offset signal from said first absorbance signal at the input of said ratio determining means.

18. A gas detecting apparatus according to Claim 15, wherein said display means comprises first and second analog meters and third and fourth function generating circuit means, said third function generating circuit means being interposed between said ratio determining means and said second meter and responsive to said ratio signal for providing a signal corresponding to the logarithm of said ratio signal for driving said first meter or a first display, and said fourth function generating circuit means being interposed between said second function generating circuit means and said second meter and responsive to said second

absorbance signal for providing a signal corresponding to the logarithm of said second absorbance signal for driving said second meter or a second display.

19. A gas detecting apparatus according to Claim 18, wherein said second meter has a scale divided into a first reading portion indicating the type of hydrocarbon as swamp gas, a second reading portion indicating the type of hydrocarbon as natural gas, a third reading portion indicating the type of hydrocarbon as ethane, a fourth reading portion indicating the type of hydrocarbon as propane, and a fifth reading portion indicating the type of hydrocarbon as gasoline vapors.

20. A selective gas detecting apparatus for determining a concentration and type or average type of hydrocarbon gas in a gas sample based upon absorption of infrared radiation by the gas sample, comprising: means for passing infrared radiation through the gas sample, infrared radiation detecting means for detecting infrared radiation passed through the gas sample and producing in a first signal channel a first measurement signal indicative of a first wavelength absorbed by the gas sample, and producing in a second signal channel a second measurement signal indicative of a second wavelength absorbed by the gas sample, processing circuit means including first circuit means responsive to said first measurement signal for providing a first output signal corresponding to a first total concentration of hydrocarbons in the gas sample, second circuit means

responsive to said second measurement signal for providing a second output signal corresponding to a second total concentration of hydrocarbons in the gas sample, ratio determining means responsive to said first and second output signals for providing a ratio signal corresponding to the ratio of said first and second output signals, said ratio signal being indicative of the type or average type of hydrocarbon gas, and display means responsive to said first output signal and said ratio signal for providing an indication of the concentration and type or average type of hydrocarbon gas in the gas sample, respectively.

21. A gas detecting apparatus according to Claim 20, wherein said first wavelength is 3.2 $\pm$ 0.1 microns and said second wavelength is 3.4 $\pm$ 0.1 microns.

22. A gas detecting apparatus according to Claim 21, wherein said infrared radiation detecting means produces a reference measurement signal indicative of a third wavelength absorbed by the gas sample, said reference measurement signal being applied to said first and second circuit means for generating said first and second output signals.

23. A gas detecting apparatus according to Claim 22, wherein said third wavelength is 2.9 $\pm$ 0.1 microns.

24. A gas detecting apparatus according to Claim 21, wherein said third wavelength is 3.9 $\pm$ 0.1 microns.

25. A gas detecting apparatus according to Claim 22, wherein said processing circuit means further comprises offset means for adjusting said ratio signal to be a preselected value when the ratio signal indicates that the type of hydrocarbon is methane.

26. A gas detecting apparatus according to Claim 25, wherein said offset means includes means for producing an offset signal and circuit means for subtracting said offset signal from said ratio signal at the output of said ratio determining means.

27. A gas detecting apparatus according to Claim 22, wherein said display means comprises first and second analog meters and first and second function circuit means, said first function circuit means being interposed between said ratio determining means and said first meter and responsive to said ratio signal for providing a signal corresponding to the logarithm of said ratio signal for driving said first meter, and said second function circuit means being interposed between said first circuit means and said second meter and responsive to said second output signal for providing a signal corresponding to the logarithm of said second output signal for driving said second meter.

28. A gas detecting apparatus according to Claim 22, further comprising alarm means responsive to said ratio signal for providing an indication whenever a measured concentration of ethane is below a preselected level.

29. A gas detecting apparatus according to Claim 23, wherein said infrared radiation detecting means comprises first, second and third infrared detectors responsive to infrared radiation at 3.4 microns, 3.2 microns, and 2.9 microns, respectively, first combining circuit means for combining signal outputs of said first and third detectors to produce said first measurement signal, and second combining circuit means for combining signal outputs of said second and third detectors for producing said second measurement signal.

30. A gas detecting apparatus according to Claim 22, wherein said first and second circuit means each comprise a low pass filter circuit and said ratio determining means comprises a function circuit providing a signal output corresponding to a quotient of said first and second output signals.

31. A selective gas detecting apparatus for determining the concentration and type or average type of hydrocarbon gas in a gas sample based upon absorption of infrared radiation by the gas sample comprising: means for passing infrared radiation through the gas sample, infrared detecting means for detecting infrared radiation passed through the gas sample including a

first infrared detector producing a first detection signal indicative of a first wavelength absorbed by the gas sample, a second infrared detector producing a second detection signal indicative of a second wavelength absorbed by the gas sample, and a reference infrared detector producing a reference signal indicative of a third wavelength absorbed by the gas sample, first signal combining circuit means for combining said reference signal with said first detection signal to produce a first measurement signal indicative of said first wavelength absorbed by the gas sample, second signal combining circuit means for combining said reference signal with said second detection to produce a second measurement signal indicative of said second wavelength absorbed by the gas sample, processing circuit means including first circuit means responsive to said first measurement signal for providing a first output signal corresponding to a first total concentration of hydrocarbons in the gas sample, second circuit means responsive to said second measurement signal for providing a second output signal corresponding to a second total concentration of hydrocarbons in the gas sample, ratio determining means responsive to said first and second output signals for providing a ratio signal corresponding to the ratio of said first and second output signals, said ratio signal being indicative of the type or average type of hydrocarbon gas, and display means responsive to said second output signal and said ratio signal for providing an indication of the concentration and type or average type of hydrocarbon gas in the gas sample, respectively.

32. A gas detecting apparatus according to Claim 31, wherein said first wavelength is 3.2 microns, said second wavelength is 3.4 microns and said third wavelength is 3.9 microns.

33. A gas detecting apparatus according to Claim 32, wherein said first wavelength is 3.2 microns, said second wavelength is 3.4 microns and said third wavelength is 2.9 microns.

34. A gas detecting apparatus according to Claim 33, wherein said processing circuit means further comprises offset means for adjusting said ratio signal to be a preselected value when the ratio signal indicates that the type of hydrocarbon is methane.

35. A gas detecting apparatus according to Claim 34, wherein said offset means includes means for producing an offset signal and circuit means for subtracting said offset signal from said ratio signal at the output of said ratio determining means.

36. A gas detecting apparatus according to Claim 31, wherein said display means comprises first and second analog meters and first and second function circuit means, said first function circuit means being interposed between said ratio determining means and said first meter and responsive to said ratio signal for providing a signal corresponding to a logarithm of said ratio signal for driving said first meter, and said second function circuit means being interposed between said first circuit means and said second meter and responsive to said

second output signal for providing a signal corresponding to the logarithm of said second output signal for driving said second meter.

37. A gas detecting apparatus according to Claim 36 wherein said first meter has a scale divided into low, intermediate and high reading portions to indicate that the type of hydrocarbon is swamp gas, or natural gas, propane or gasoline vapors, respectively.

38. A gas detecting apparatus according to Claim 33, further comprising alarm means responsive to said ratio signal for providing an indication whenever the measured concentration of thane is below a preselected level.

39. A method of determining a concentration and type or average type of hydrocarbon gas in a gas sample comprising: passing infrared radiation through the gas sample, detecting infrared radiation passed through the gas sample, producing in a first signal channel a first measurement signal indicative of a first wavelength absorbed by the gas sample and corresponding to a first total concentration of hydrocarbons in the gas sample, producing in a second signal channel a second measurement signal indicative of a second wavelength absorbed by the gas sample and corresponding to a second total concentration of hydrocarbons in the gas sample, obtaining a ratio of the first and second measurement signals to produce a ratio signal indicative of the

type or average type of hydrocarbon gas and applying the second measurement signal and the ratio signal to first and second analog meters to provide an indication of the concentration and type or average of hydrocarbon gas, respectively, in the gas sample.

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